ORDA Suncheck Part 2

Suncheck Part 2 computes Sun Noise Temperature using two techniques, measured and expected. The measured and expected values are compared against each other to determine Antenna Gain, which includes differences in Antenna Gain and the Microwave Loss from Antenna to Receiver Protector. Expected Sun Noise Temperature is based upon Sun Flux measured by external calibration (typically Penticton), site location and radar characteristics.

Measured Sun Noise Temperature is based on four measurements:

1. Noise away from the sun ("blue sky noise") with calibrated Noise Source OFF
2. Noise away from the sun ("blue sky noise") with calibrated Noise Source ON
3. Noise on the sun with calibrated Noise Source OFF
4. Noise on the sun with calibrated Noise Source ON

Expected Noise Temperature

For Expected Noise Temperature, the following equation is used (from "On Measuring WSR-88D Antenna Gain Using Solar Flux", Sirmans and Urell, Jan 2001):

$$T_C = \frac{g * \lambda^2 * sfu * \left(10^{-22}\right)}{4\pi * 2 * B} \times \frac{10^{\frac{RML}{10}}}{\left[1 + 0.18 * \left(\frac{\theta_S}{\theta_3}\right)^2\right]^2} \times \frac{1}{DC}$$

Where:

g	Current Antenna Gain converted to ratio from dB in adaptation data
λ	Wavelength
sfu	Solar Flux Units as reported by Observatory (typically Penticton)
10^{-22}	Convert sfu to watts
4π	Related to antenna gain
2	Correction for single polarized solar flux
B	Boltzmann's Constant
RML	Receiver Microwave Loss in dB from antenna to receiver protector, from adaptation data
θ_S	Angle subtended by sun
θ_3	Antenna 3dB beamwidth, from adaptation data
DC	Distance correction for earth-sun

For this equation, the following variables need to be calculated/measured/corrected:

Variable	Calc/Meas/Corr	Legacy vs ORDA
λ	Calculated from site frequency	Same
sfu	Corrected for frequency	Manual vs. Automatic
RML	Added from adaptation data	Same
θ_S	Calculated from frequency	Optic Sun vs. Radio Sun
DC	Calculated from Lat/Long and earth's eccentricity	Different algorithm

Three variables will have slightly different values between the Legacy system and the ORDA system. The estimated differences are:

Variable	Difference

sfu	-0.5 to +0.5. Legacy accuracy is within 1dB (input only as an integer value), while ORDA is calculated as a floating point number
θ_S	0.088dB, the difference between radio sun and optical sun in S band
DC	Negligible. The AU calculation in ORDA is more accurate, but the difference will not be discernible.

Measured Sun Temperature

The measured sun temperature uses a calibrated noise source to compare noise power readings. Noise Power measurement are taken using the same methodology in both the Legacy system and the ORDA system. However, the equations used to compute noise temperature are different. The ORDA equation has been corrected for an error noted in the Legacy equation.

Legacy equation for Sun Noise Temperature

$$T_N = 290\left(10^{\left(\frac{Noise_{source}+Noise\_Path}{10}\right)}\right) = 290\left(10^{\left(\frac{ENR}{10}\right)}\right)$$

$$T_S = \frac{T_N}{\frac{P_{N2}}{P_S}-1} - \frac{T_N}{\frac{P_N}{P_C}-1}$$

where:

Value	Explanation
P_C	Antenna Power Level at IFD
T_N	Temperature of Noise Source at Receiver Front End
P_N	Power Level at IFD with Noise Source turned on pointed at blue sky
T_S	Sun Temperature, what we're looking for
P_S	Power Level at IFD when we're pointed at the sun
P_{N2}	Power Level at IFD with noise source on pointed at the sun
$Noise_{source}$	Noise Power Level from Noise Source, in dB
Noise_Path	Loss from Noise Source to Front End Injection, in dB
ENR	Excess Noise Ratio, Noise Power Level injected into Front End, in dB

ORDA equation for Sun Noise Temperature

Equation for Noise Temperature of Noise Source injected into system:

$$T_N = 290\left(10^{\left(\frac{Noise_{source}+Noise\_Path}{10}\right)}+1\right) = 290\left(10^{\left(\frac{ENR}{10}\right)}+1\right)$$

First, we need the value of the Noise Temperature pointed away from the sun (at Blue Sky):

$$T_R = \frac{\left(T_N - T_C \frac{P_N}{P_C}\right)}{\left(\frac{P_N}{P_C} - 1\right)}$$

We then use this result to calculate the Sun Temperature:

$$T_S = \frac{\left(T_N - T_R\left(\frac{P_{N2}}{P_S} - 1\right)\right)}{\left(\frac{P_{N2}}{P_S} - 1\right)}$$

Value	Explanation
T_C	Blue Sky Antenna Temperature measured at Receiver Front End
P_C	Antenna Power Level at IFD
T_N	Temperature of Noise Source at Receiver Front End
P_N	Power Level at IFD with Noise Source turned on pointed at blue sky
T_S	Sun Temperature, what we're looking for
P_S	Power Level at IFD when we're pointed at the sun
P_{N2}	Power Level at IFD with noise source on pointed at the sun
T_R	Receiver Noise Temperature pointed at Blue Sky
$Noise_{source}$	Noise Power Level from Noise Source, in dB
Noise_Path	Loss from Noise Source to Front End Injection, in dB
ENR	Excess Noise Ratio, Noise Power Level injected into Front End, in dB

Difference in Legacy and ORDA Measured Sun Noise Temperature

The assumption for the legacy equations is that the cold source for measurements is 290K. This assumption is valid if the cold source is a dummy load. However, both our cold sources for the two Noise Temperature measurements made are not dummy loads. One is the antenna pointed at Blue Sky (cold source approximately 95K) and the other is with the antenna pointed at the Sun (cold source over 10,000K, depending on solar flux). These differences actually create only a small error (Based on ORDA testing and analysis, the error is approximately 0.2dB).

The difference between Legacy KCRI Channel 2 (2995MHz) and ORDA KCRI Channel 2 measurements is 0.85dB (with ORDA measurements being 0.85dB lower than Legacy). This means that Legacy KCRI Channel 2 measures approximately 0.3dB above Calculated Antenna Gain and ORDA KCRI Channel 2 measures approximately 0.45dB below Calculated Antenna Gain.

The difference between Legacy KCRI Channel 1 (2950HMz) and ORDA KCRI Channel 1 measurements is 0.60dB (with ORDA measurements being 0.60dB lower than Legacy). ORDA KCRI Channel 1 consistently measures approximately -0.45dB, while Legacy KCRI Channel 1 measures close to 0 (with the other 0.15 in difference due to different Expected Sun Temperatures).

The strong correlation between ORDA KCRI Channel 2 & ORDA KCRI Channel 1 measurements provides high confidence in ORDA measurements. The difference in Legacy Channel 2 and Channel 1 comparisons is not understood.

Further support is the fact that ORDA has been running consistently colder than KTLX in all Data Quality comparisons. Reflectivity analysis has shown that ORDA is 1-2 dB colder than KTLX. Correcting for an antenna gain 0.45dB lower than calculated would make ORDA 0.9dB hotter; therefore, much closer to KTLX. The measured Legacy antenna gain of 0.3dB higher than calculated would make the ORDA system even colder; thereby much further from KTLX.

Previous legacy measurements of Antenna Gain at KCRI have consistently shown an antenna gain less than calculated (ref "WSR-88D Super-Calibration Case History", Bill Urell, 27 August 1999, page 2). This data differs from current measurements and implies a problem with the Legacy measurement.

ORDA Measured Sun Temperatures

Measurements taken on different days at different times with different solar fluxes shows that the ORDA Measured Sun Temperature is very consistent. The data is provided in the following chart showing data from both KCRI Channel 2 and KCRI Channel 1:

System	Date	Time	Measured Sun Temp	Expected Sun Temp	Gain Diff
KCRI2	11/9/2004	20:16:38	10588.7	11822.70	-0.48
KCRI2	11/9/2004	20:21:05	10256.6	11269.05	-0.41
KCRI2	11/9/2004	20:22:04	10452.4	11269.05	-0.33
KCRI2	11/9/2004	20:23:05	10056.1	11269.06	-0.49
KCRI2	11/9/2004	20:24:12	10333.5	11269.06	-0.38
KCRI2	11/9/2004	20:25:15	10002.1	11269.06	-0.52
KCRI2	11/9/2004	20:26:22	10102	11269.06	-0.47
KCRI2	11/9/2004	20:28:17	10566.3	11269.06	-0.28
KCRI2	11/9/2004	20:29:18	9927.3	11269.07	-0.55
KCRI2	11/9/2004	20:30:26	9987.86	11269.07	-0.52
KCRI2	11/9/2004	20:31:41	9746.13	11269.07	-0.63
KCRI2	11/15/2004	21:10:07	8276.28	9353.33	-0.53
KCRI2	11/15/2004	21:13:17	8291.07	9353.33	-0.52
KCRI2	11/15/2004	21:16:26	8380.06	9353.34	-0.48
KCRI2	11/15/2004	21:19:35	8542.87	9353.34	-0.39
KCRI2	11/15/2004	21:22:16	8487.21	9353.34	-0.42
KCRI2	11/15/2004	21:24:52	8416.21	9353.34	-0.46
KCRI2	12/9/2004		7127.9	7743.3	-.35
KCRI2	12/9/2004		6797.0	7743.3	-.57
KCRI2	12/9/2004		6944	7743.3	-.47
KCRI1	12/12/2004		7769.57	8547.77	-0.41
KCRI1	12/12/2004		7973.07	8547.77	-0.3
KCRI1	12/12/2004		7582.15	8547.77	-.52
KCRI1	12/12/2004		7598.98	8547.77	-.51
KCRI2	12/12/2004		7275.47	8309	-.58
KCRI2	12/12/2004		7509.04	8309	-.44
KCRI2	12/12/2004		7398.69	8309	-.50